SUMMARY

Holism and reductionism are usually seen as opposite and mutually exclusive approaches to nature. Recently, some have come to see them as complementary rather than mutually exclusive. In this book I have argued that, even stronger, they should be seen as mutually dependent and co-operating research programmes. I have discussed holism and reductionism in biology in general (part 1) and in ecology in particular (part 2).

After an introductory chapter (1) I have provided an overview of holistic and reductionistic positions in biology, and of the reduction problems to which they relate (chapter 2). I have argued that it is extremely important to distinguish between ontological, epistemological and methodological aspects of these problems. The overview has shown that there are actually several approaches to reduction problems in biology, which can be characterized as more or less radically or moderately holistic or reductionistic. It has shown also that there are three major 'contradistinctions' between holism and reductionism in biology, to wit (1) the doctrine of emergence versus the reduction thesis; (2) functional explanations versus causal explanations; and (3) phenomenology versus mechanicism (and, coupled to 2 and 3, synthesis versus analysis). In later chapters I have shown that these 'contradistinctions' are not really contradistinctions at all.

In the next chapters I have discussed the terms 'reduce' and 'reduction' in science. In chapter 3 I have discussed the reduction of laws and theories. I have shown that there are many different types of reduction depending on the auxiliary hypotheses that are being used in addition to the reducing theory: approximation-, aggregation, correlation and/or identification-hypotheses. The distinctions between these types has later, in chapter 5, proved to be of great importance in (re)defining the concept of 'emergence'. The major conclusion of chapter 3 was that reduction is an epistemological issue, pertaining to logical relations between statements or systems of statements (theories). It should not be confused, therefore, with 'ontological reduction', certainly not in one of its ordinary senses, such as diminishing, devaluating or the like. Scientific reductions are, with the exception of instrumentalistic reductions, kinds of explanation, and, moreover, non-eliminative kinds of explanation. This means that a reduced law or theory is not eliminated by the reducing theory but rather consolidated or even reinforced. The ontology of the reduced law or theory (the objects, attributes, phenomena or events to which it refers) is thereby also being consolidated.

In chapter 4 I have argued that the same holds for reductions of concepts. Concept reductions are supposed to be accomplished by means of so-called ontological identity relations, which are in turn supposed to connect terms in the law or theory to be reduced, which do not occur in the reducing theory, with theoretical terms of the reducing theory. Because they are called ontological identity relations, several philosophers have thought that concept reductions imply some form of ontological reduction. And because they often occur in the context of micro-reductions, some have even thought that concept reductions are themselves micro-reductions. As a result, the idea has arisen that ontological identity relations are connections between macro-concepts (at the level of the whole) and micro-concepts (at the level of the parts). However, concept reductions by means of ontological identity relations cannot be micro-reductions, because micro-reduction is, by definition, reduction with an aggregation step. Moreover, ontological identity relations are relations between different representations (concepts) of and the same type of thing or attribute. That is, they express different epistemological sides of the same ontological coin. Therefore, concept reductions cannot be considered ontological reductions either, certainly not (once more) in the ordinary sense of diminishing, devaluating or the like. Thus, concept reduction is, like law or theory

reduction, an epistemological issue: it pertains to relations between, in this case, different concepts or representations of one and the same type of thing or attribute. 'Ontological reduction', then, may, in the context of scientific reductions, actually be considered a contradiction of terms.

In chapter 5 I have linked this conclusion to the emergence thesis and to the alleged contradistinction between this thesis and the reduction thesis. I have shown that the doctrine of emergence actually consists of two separate claims, namely (1) an ontological thesis stating that a whole has emergent properties which the component parts do not possess, neither separately nor in other partial combinations; and (2) an epistemological thesis stating that emergent properties of wholes are 'in principle' irreducible. I have argued that the first claim may be regarded as a valid, universal thesis about relations between properties of wholes and properties of parts, but that the second claim is untenable. I have discussed many emergent properties (in the sense of thesis 1) of wholes, biological as well as physico-chemical, that have proved to be explainable in terms of micro-theories about the component parts and auxiliary hypotheses. Once again, however, it is important to realize that reduction is an epistemological issue, whereas emergence, in the sense of thesis (1), is an ontological one. It is not 'wholes' or 'emergent properties of wholes' that are being reduced but statements about them. Reduction is a kind of explanation, not of explaining-away. Thus, it leaves the ontology of whatever is reduced fully intact. I have developed a new definition of the term 'emergence' which expresses emergence in terms of the auxiliary hypotheses that may be used in reductions, in particular aggregation-, correlation- and identification-hypotheses. This has even lead to two very remarkable conclusions. First, emergence may be considered the opposite of ontological identity. And second, if there were no emergence, there wouldn't be any (micro-) reductions either. (If there were only ontological identities in this world, there would be no different types of things and hence nothing for scientists (who would not exist) to reduce.) In this respect, therefore, there is absolutely no contradistinction between holism and reductionism. On these grounds (among others) I have introduced my thesis that holism and reductionism should rather be seen as mutually dependent, and hence co-operating, research programmes than as conflicting views of nature or of relations between sciences. Holistic programmes play an important role in science as guide programmes for reductionistic programmes by discovering or developing macro-laws or -theories about (emergent) phenomena at the level of wholes, which they themselves, however, cannot explain. For these explanations they depend on the fruits of reductionistic programmes. If the latter succeed in providing the explanations (reducing the macro-laws or -theories) they act as supply programmes for the holistic guide programmes. Reductionistic programmes depend in turn on holistic programmes for providing the macro-laws or -theories that call for these (deeper) explanations.

In chapter 6 I have discussed an example of this mutual dependency in the form of the reduction of the Bohr-effect in animal physiology. I have shown that this law has been reduced to the theory of allostery, applied to hemoglobin molecules in red blood cells, and that this application of the theory of allostery has been reduced to the theory of chemical bonding. I have also shown that at least six research programmes were involved in these reductions, and that the relations between these programmes can be characterized very well in terms of the model of holistic guide programmes and reductionistic supply programmes. The only, but highly significant, qualification appearing from example was that the terms 'holistic' and 'reductionistic' are extremely relative and should always be related to a certain

given level of organization.

In chapter 7 I have resolved the remaining contradistinction between holism and reductionism in biology, viz. the need for functional explanations (coupled to holism in the form of organicism) and the ('reductionistic') demand that explanations be causal. I have shown that functional explanations are perfectly legitimate explanations which in a sense can be reconstrued as causal explanations. I have argued that functional explanations are indispensable components of more comprehensive, causal-evolutionary explanations, because the latter appeal to the adaptive value, and hence the function, of the property to be explained. In that sense functions can be regarded as adaptations, and functional explanations can be regarded as a sort of 'short-hand' for (causal) evolutionary explanations. Finally, I have shown that in the context of functional explanations, too, co-operation of holistic and reductionistic research programmes occurs.

In part 2 I have applied my thesis to ecology. I have shown that in ecology too, holism-reductionism disputes notwithstanding, co-operation of holistic and reductionistic research programmes occurs (chapters 11 and 12), or, in so far as this appears to be not the case, that it should be strived after (chapter 13).

In chapter 8 I have given an overview of reduction problems in ecology and of the various approaches to these problems. I have noticed that in ecology, too, there are several, radical, moderate and anti-reductionistic research strategies, with respect to the levels of both ecosystems, communities and populations. I have also noticed, however, that concrete solutions to reduction problems in ecology (in the sense of my thesis) are frustrated by what is called the intellectual immaturity or the anomalous status of ecology. This refers to the almost complete lack of general laws and theories in ecology, at least at the higher levels of communities and ecosystems. Of a number of possible causes I have lifted out two, which lend themselves to philosophical (conceptual) analysis and clarification. The first one is the ambiguity of a major part of the ecological vocabulary. This was the subject of chapters 9 and 10. The second is the inhibitory effect which holism-reductionism disputes (may) have on the growth of knowledge (such as theory development and maturation). This was the subject of chapter 13.

In chapter 9 I have discussed the concept of an (ecological) community. It appeared that the term 'community' is used for several different entities at various levels of organization. This ambiguity alone seems to be sufficient for the lack of 'general' laws and theories about 'communities'. My purpose in chapter 9 was to try and contribute to a solution of this problem. In doing so I have argued, first, that it seems wise to use the term 'community' only for groups of species belonging to a single taxonomic or phylogenetic group (in the sense of plant communities, bird communities, etcetera), and to use the term 'biocoenosis' (as before) for the higher level of organization, defined as the biotic component of an ecosystem. Next I have argued that, although species within communities may of course interact with each other, interaction is itself not a necessary or sufficient condition for community membership. Finally, I have hit upon what is known as the most notorious problem in community ecology, to wit the boundary problem, as well as the problem of heterogeneity. I have found that the cause of these problems lies in the fact that communities are almost invariably being seen (defined) as groups of populations occurring together in space and time, whereas the empirical fact is rather that populations of different species mostly do not occur together in the same space, and, moreover, that the species composition of communities changes continuously. This has lead to the suggestion that a community had better be defined as the group of individuals

of two or more species occurring in the area of intersection of populations of these species. It is only in such intersection areas that one can really talk of the co-occurrence (coexistence) of (individuals of different) species. I have shown the empirical adequacy of this definition by discussing various salt marsh plant communities on the Dutch island of Schiermonnikoog.

In chapter 10 I have clarified two other important, yet highly controversial, concepts in ecology, to wit habitat and niche. It appeared that there are at least four different habitat concepts in ecology, and as many niche concepts, the additional complication being that two of these habitat concepts correspond to two of these niche concepts, whence the distinction between habitat and niche is blurred. In addition, different habitat concepts (and hence niche concepts) appeared to correspond to different environment concepts and also to different biotope concepts. My purpose in chapter 10 was to disentangle all these concepts from one another and to supply each of them with a suitable term. I have done so by keeping a close eye on commonly accepted notions about habitat differentiation and niche differentiation, two 'principles' allowing one to explain the coexistence or non-coexistence of species in communities. The results can be found in boxes 5 and 7 in chapter 10.

In chapter 11 I was finally able to substantiate my claim that in ecology, too, co-operation of holistic and reductionistic research programmes occurs. I have discussed the reduction of the classical competition model of Lotka and Volterra to modern niche theory (employing, of course, one of the niche concepts discussed in chapter 10). The Lotka/Volterra model is a phenomenological (holistic) model: it describes the possible effects of competition between two species. Modern niche theory, on the other hand, is a mechanistic theory (set of models), in which both the objects of competition (resources) and a mechanism (exploitation of resources by two or more species) are being specified. I have shown that the reduction was established with the help of a relatively simple identification hypothesis and two relatively simple aggregation hypotheses, making it yet another example of heterogeneous micro-reduction in biology. In the reduction, the Lotka/Volterra model acted as a holistic guide programme and modern niche theory acted as a reductionistic (reductive) supply programme.

In chapter 12 I have discussed another example of co-operation in the form of the approximative reduction of MacArthur and Wilson's equilibrium theory of island biogeography. I have argued that this can be seen as a holistic model, which has been of great unifying and especially heuristic value, but which in time has been found to be a bit too simple and in some respects had to be corrected. Therefore, it can also be seen as an idealization in the sense of the model of idealization and concretization (discussed in chapter 3), which subsequent research programmes have concretized (that is, corrected). Because these concretizations have a reductive (be it approximative) character, we can see in this structure of idealization and concretization yet another example of the co-operation of holistic and reductionistic research programmes in ecology. A philosophically interesting side-conclusion was that the model of idealization and concretization thus appears to apply also to relations between research programmes, and not only to programme-internal developments.

In chapter 13 I have discussed an example of the inhibitory effect that holism-reductionism disputes may have on the growth of knowledge. The example concerns a controversy in island biogeography (between two of the programmes involved in concretizations of the MacArthur/Wilson model) over the role of interspecific competition in structuring (island) communities. This controversy has lasted for about ten years, appeares to have died out rather than to have been resolved, and has produced nothing new in the field of explanations of community structure. I have shown that the major factors underlying the controversy were

differing, *in casu* (radical) holistic and reductionistic, views of communities. Though this presented a problem for my thesis, I have argued that, ultimately, the controversy can be resolved, and in a sense has been resolved, in a way that corroborates my thesis.

In the epilogue, finally, I have mentioned some remaining problems concerning the adequacy of the present reduction model in dealing with reduction in ecology. These problems pertain to (1) the question of specificty of ecological laws and theories, (2) the likelihood that reductions in ecology generally occur on the basis of several reducing micro-theories, and (3) the possible relationship between the former two points.